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THE COLORS OF FISHES.

DAVID STARR JORDAN.

Pigmentation.—The colors of fishes are in general produced by oil sacs or pigment cells beneath the epidermis or in some cases beneath the scales. Certain metallic shades, silvery blue or iridescent, are produced, not by actual pigment, but, as among insects, by the deflection of light from the polished skin or the striated surfaces of the scales. Certain fine striations give an iridescent appearance through the interference of light.

The pigmentary colors may be divided into two general classes, ground coloration, and ornamentation or markings. Of these the ground color is most subject to individual or local variation, although usually within narrow limits, while the markings are more subject to change with age or sex. On the other hand, they are more distinctive of the species itself.

Protective Coloration.—The ground coloration most usual among fishes is protective in its nature. In a majority of fishes the back is olivaceous or gray, either plain or mottled, and the belly white. To birds looking down into the water, the back is colored like the water itself or like the bottom below it. To fishes in search of prey from below, the belly is colored like the surface of the water or the atmosphere above it.

In shallow waters or in rivers the bottom is not uniformly colored. The fish, especially if it be one which swims close to the bottom, is better protected if the olivaceous surface is marked by darker cross streaks and blotches. These give the fish a closer resemblance to the weeds about it or to the sand and stones on which it lies. As a rule, no fish which lies on the bottom is ever uniformly colored.

In the open seas, where the water seems very blue, blue colors, and especially metallic shades, take the place of olivaceous gray or green. As we descend into deep water, especially in the warm seas, red pigment takes the place of olive. At a depth of 50 to 150 fathoms in the tropics a large percentage of the fishes are of various shades of red. Several of the large groupers of the West Indies are represented by two color forms, a shore form in which the prevailing shade is olive green, and a deeper water form which is crimson. In one case an intermediate color form also exists, which is lemon yellow. On the coast of California is a band-shaped blenny which appears in three colors, according to its surroundings, blood red, grass green, and olive yellow. The red coloration is also essentially protective, for the region inhabited by such forms is the zone of the rose-red algæ. In the arctic waters, and in lakes where rose-red algæ are not found, the red ground coloration is almost unknown, although red may appear in markings or in nuptial colors. It is possible that the red, both of fishes and algæ, in deeper water is related to the effect of water on the waves of light, but whether this should make fishes red or violet has never been clearly understood. It is true, also, that where the red in fishes ceases violet black begins.

In the great depths, from 500 to 4000 fathoms, the ground color in all fishes becomes deep black or violet black. This shade is also protective. In these depths the sun's rays scarcely penetrate, and the fish and the water are of the same apparent shade, for black coloration is here the mere absence of light.

In general, the markings of various sorts grow less distinct with the increase of depth. Bright red fishes of the depths are usually uniform red. The violet-black fishes of the oceanic abysses show no markings whatever (luminous gland excepted), and in deep waters there are no nuptial or sexual differences in color.

Ground colors other than olive green, gray, brown, or silvery rarely appear among fresh-water fishes. Marine fishes in the tropics sometimes show as ground color bright blue, grass green, orange yellow, or black; but these showy colors are almost confined to fishes of the coral reefs, where they are often associated with elaborate systems of markings.

Protective Markings. — The markings of fishes are of almost every conceivable character. They may be roughly grouped as protective coloration, sexual coloration, nuptial coloration, recognition colors, and ornamentation, if we may use that term for brilliant hues which serve no obvious purpose to the fish itself.

Examples of protective markings may be seen everywhere. The flounder which lies on the sand has its upper surface covered with sandlike blotches, and these again will vary according to the kind of sand it imitates. It may be true sand or crushed coral or the detritus of lava, in any case perfectly imitated.

Equally closely will the markings on a fish correspond with rock surroundings. With granite rocks we find an elaborate series of granitic markings, with coral rocks another series of shades, and if red corals be present, red shades of like appearance are found on the fish. Still another kind of marks indicates rock pools lined with the red calcareous algæ called Corallina. Black species are found in lava masses, grass-green ones among the fronds of ulva, and olive-green among Sargassum or fucus, the markings and often the form corresponding to the nature of the algæ in which the species makes its home.

Sexual Coloration. — In many groups of fishes the sexes are differently colored. In some cases bright red, blue, or black markings characterize the male, the female having similar marks, but less distinct, and the bright colors replaced by olive, brown, or gray. In a few cases, however, the female has marks of a totally different nature, and scarcely less bright than those of the male.

Nuptial Coloration. — Nuptial colors are those which appear on the male in the breeding season only, the pigment afterwards vanishing, leaving the sexes essentially alike. Such colors are found on most of the minnows and dace (Cyprinidæ) of the rivers and to a less degree in some other fresh-water fishes, as the darters (Etheostominæ) and the trout. In the minnows of many species the male in spring has the skin charged with bright pigment, red, black, or bright silvery, for the most part, the black most often on the head, the red on the head and body, and the silvery on the tips of the fins.

At the same time other markings are intensified, and in many species the head and sometimes the body and fins are covered with warty excrescences. These shades are most distinct on the most vigorous males, and disappear with the warty excrescences after the fertilization of the eggs.

Nuptial colors do not appear among marine fishes, and in but few families are the sexes distinguishable by differences in coloration.

Recognition Marks. — Under the head of "recognition marks" may be grouped a great variety of special markings, which may be conceived to aid the representatives of a given species to recognize each other. That they actually serve this purpose is a matter of theory, but the theory is plausible, and these markings have much in common with the white tail feathers, scarlet crests, colored wing patches, and other markings regarded as recognition marks among birds.

Among these are ocelli, black or blue ringed with white or yellow, on various parts of the body; black spots on the dorsal fin; black spots below or behind the eye; black, red, blue, or yellow spots variously placed; crossbars of red or black or green, with or without pale edges; a blood-red fin among pale ones or a fin of shining blue; a white edge to the tail; a yellow, blue, or red streamer to the dorsal fin, a black tip to the pectoral or ventral; a hidden spot of emerald in the mouth or in the axil; an almost endless variety of sharply defined markings, not directly protective, which serve as recognition marks, if not to the fish itself, certainly to the naturalist who studies it.

These marks shade off into an equally great variety for which we can devise no better name than "ornamentation." Some fishes are simply covered with brilliant spots or bars or reticulations, their nature and variety baffling description, while no useful purpose seems to be served by them, unless we stretch still more widely the convenient theory of recognition marks.

In many cases the markings change with age, certain bands, stripes, or ocelli being characteristic of the young and gradually disappearing. In such cases the same marks will be found permanent in some related species of less differentiated coloration. In such cases it is safe to regard them as ancestral.

In case of markings on the fins and of elaborate ornamentation in general, it is best defined in the oldest and most vigorous individuals, becoming intensified by degrees.

Intensity of Coloration. — In general, coloration is most intense and varied in certain families of the tropical shores, and especially about coral reefs. But in brilliancy of individual markings some fresh-water fishes are scarcely less notable, especially the darters (Etheostominæ) and sunfishes (Centrarchidæ) of the streams of eastern North America. The bright hues of these fresh-water fishes are, however, more or less concealed in the water by the olivaceous markings and dark blotches of the upper parts.

Coral Reef Fishes. — The brilliantly colored fishes of the tropics seem to scorn the need of protective coloration. They save themselves from their enemies in most cases by excessive alertness and activity (Chætodon, Pomacentrus), or else by burying themselves in coral sand (*Jules gaimardi*), a habit more frequent than has been suspected.

Fading of Pigments in Spirits. — In the preservation of specimens most red and blue pigments fade to whitish, and it requires considerable care to interpret the traces which may be left of red bands or blue markings. Yet some blue pigments are absolutely permanent, and occasionally blood-red pigments persist through all conditions. Black pigment seldom changes in spirits, and olivaceous markings simply fade a little without material alteration. It is an important part of the work of the systematic ichthyologist to learn to interpret the traces of the faded pigment left on specimens he may have occasion to examine. In such cases it is more important to trace the markings than to restore the ground color, as the ground color is at once more variable with individuals and more constant in large groups. In other words, it varies a good deal, but in almost constantly narrow limits.

Variation in Pattern. — Occasionally, however, a species is found in which, other characters being constant, both ground color and markings are subject to a remarkable range of variation. In such cases the actual unity of the species is open to serious question. The most remarkable case of such variation known is found in a West Indian fish, the vaca, which bears the incongruous name of *Hypoplectrus unicolor*. In the typical vaca the body is orange with black marks and blue lines, the fins checkered with orange and blue. In a second form the body is violet, barred with black, the head with blue spots and bands. In another form the blue on the head is wanting. In still another the body is yellow and black, with blue on the head only. In others the fins are plain orange, without checks, and the body yellow, with or without blue stripes and spots, and sometimes with spots of black or violet. In still others the body may be pink or brown, or violet black, the fins all yellow, part black or all black. Finally, there are forms deep indigo blue in color everywhere, with cross bands of indigo black, and these again may have bars of deeper blue on the head or may lack these altogether. I find no difference among these fishes except in color, and no way of accounting for the differences in this regard.

A species of puffer (*Tetradon setosus*) shows similar remarkable variations, being dark gray with white spots, but varying to indigo blue, lemon yellow, or sometimes having coarse blotches of either. Lemon-yellow varieties of several species are known, and these may be due to a failure of pigment, a sort of semi-albinism. True albinos, individuals wholly without pigment, are rare among fishes.